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Direct Power Control Algorithm for Electric Traction Systems

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Abstract:

In this paper presents a direct power control-based algorithm is used for general filtering and unbalance compensation scheme for electric traction systems. This method can improve the power flow exchange between the grid and the load . As a result unbalanced load is seen as a balanced linear load. The proposed filter is evaluated on power substations for two-level and dual-converter in the power stage. This method is experimented simulated and shown a better oerformance.

I. Introduction

The electric traction systems for passengers and freight use various power transformer configurations, in order to feed single-phase systems from the three-phase supply. In general, three-phase to two single-phase conversion schemes use transformers connected in open delta (V-V), Scott or Le Blanc configurations, to improve the power system balance. However, in practical applications these transformer connections do not solve the unbalance problem seen from the three-phase side, due to the variable demands in the transport system and railroad line profile.

These problems are usually addressed, in practice, with the use of passive power quality compensators such as reactive power compensation capacitors and passive filters, and they are single-phase equipment installed in each feeder from the traction substation. Usually, the coupling factor between two feeders is negligible due to the independent operation of each passive compensator. Moreover, passive equipment does not have the dynamic capability to adjust to changes in load, where over and under compensation happen frequently as a result of continuous changes in load conditions. There are different active power quality compensators proposed in the literature, to solve the unbalance problem, but they neglect the sequence components introduced by harmonics. Also, all of them employ two single-phase converters that have a common dc bus, but they cannot provide simultaneous compensation of unbalance and harmonic content. However, for the compensation made from the three-phase side, the use of the instantaneous active and reactive power definition provides a way for simultaneous compensation of unbalance and harmonics. The traction system under study is similar to the stage 1 railway Ezequiel Zamora in Venezuela. It draws power using a Scott transformer (115/25 kV, 60 Hz, 40 MVA). This transformer provides two single-phase lines with a 90◦ phase shift between them. One of the single-phase lines feeds both ways of the Charallave–Caracas section (24 km), with a ramp of 3.125%. The other single-phase line feeds both ways of the CharallaveCua section (17.5 km), with less traffic and a ramp of 0.6%, resulting in less load for this phase. For this configuration, the Scott transformer has an unbalance in the range of 12–20% in normal operation, and 40% for emergency operation.

NEW TRENDS IN DRIVE CONCEPTS

A. On-Board Energy Storage

Energy storages are of interest for intermediate storage of the brake energy, for reduction of the peak power demand and infrastructure losses, to enable short sections without catenary in historic cities, in shops or at track works and for relieving a diesel motor at acceleration, rated for the average power only. Flywheel storages have been tested in hybrid busses and trams, e.g. in Rotterdam. They are built of very strong carbon-fibre materials and driven by inverter-fed permanent-magnet synchronous machines (PMSM); the maximum attained speed is at 12,000 rpm, the usable energy 1.5...2 kWh. Supercap storages, coupled with two-quadrant converters to the DC link, have been tested for several years at the municipal tramways of Mannheim; now an order of 18 trains for Heidelberg is under delivery (Bombardier MITRAC Energy Saver). Nice City Light Rail is bridging wireless sections, not equipped with overhead contact line, of less than 450 m by means of a NiMH high-performance battery, since July 2007.

B. Permanent-Magnet Synchronous Motors

Recently new technologies for synchronous motors, like the permanently-excited type with rare-earth magnets (PMSM,), fed from individual IGBT inverters, are under test. As they offer a considerably higher power-toweight ratio than induction motors, they are most promising for HSTs and low-floor suburban and tram equipment, where "each cubic centimetre counts". There are two main development lines:

1) Conventional drive construction

That means standard drive construction with gears and elastic coupling, as used e.g. in the new AGV drive. The drive has proven its performance when boosting the TGV V150’s maximum speed to 574.8 kph on 3rd of April, 2007. A first series of 25 trains is under delivery for the Italian railway enterprise NTV. ALSTOM markets PMSM in new CITADIS low-floor tramway cars.

II. Multilevel Compensation

Fig. 3 shows the open delta transformer (V-V) used to connect a traction substation to the electric grid, while the voltage space vector calculated in (11) is synthesized with the dual converter modulation technique presented.
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Harmonic Distortion:

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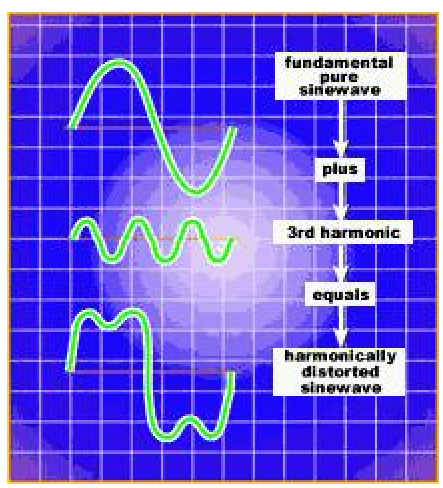
As the current distortion is conducted through the normal system wiring, it creates voltage distortion according to Ohm's Law. While current distortion travels only along the power path of the non-linear load, voltage distortion affects all loads connected to that particular bus or phase.

Current distortion affects the power system and distribution equipment. It may directly or indirectly cause the destruction of loads or loss of product. From the direct perspective, current distortion may cause transformers to overheat and fail even though they are not fully loaded. Conduc tors and conduit systems can also overheat leading to open circuits and downtime.

On three-phase wye systems, current distortion causes higher than expected currents in shared neutrals. A shared neutral is one that provides the return path for two or three-phases. Currents as high as 200% of the phase conductors have been seen in the field. This large level of current can easily burn up the neutral creating an open neutral environment. This open neutral creates voltage swells and overvoltages. These voltage conditions easily destroy equipment, particularly power supplies. Another indirect problem introduced by current distortion is called resonance. Certain current harmonics may excite resonant frequencies in the system. This resonance can cause extremely high harmonic voltages, possibly damaging equipment. There is one additional comment about current distortion. When the current is non-sinusoidal, our conventional ammeters and voltmeters will not respond accurately. To accurately measure currents that are harmonically distorted, use a True-RMS meter. This applies equally to distorted voltages.



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Voltage distortion, on the other hand, directly affects loads. Distorted voltage can cause motors to overheat and vibrate excessively. It can also cause damage to the motor shaft. Even non-linear loads are prey to voltage distortion. Equipment ranging from computers to electronically-ballasted fluorescent lights may be damaged by voltage distortion. If damage occurs due to current distortion, except for high neutral current, then one solution is to reduce the distortion. There are three methods for this. First, a passive filter can be used to reduce the current from one or two specific harmonics. In the second method, an active filter reduces all the harmonic currents. It is more costly and complex to use, but it works better than passive filters. The third method involves the use of transformers. Delta-wye transformers reduce certain harmonics, particularly what are called zero sequence harmonics. Zig-zag transformers can also be used to reduce zero sequence harmonics, but without changing the system type between delta and wye. In addition, they can help reduce high neutral currents. If there is concern that these special transformers or the regular distribution transformers may overheat, then transformer derating, or the use of K-rated transformers, is recommended. If high neutral currents are the culprit, then the first step is to eliminate shared neutrals wherever possible. Where this cannot be done, try oversizing the neutral wire so it won't overheat. If this doesn't work, then the distortion must be reduced as described above. There are two ways to reduce voltage distortion. Remember that internal voltage distortion is the result of the business's non-linear loads interacting with the wiring. The first way to reduce the distortion is to reduce the harmonic current. The second way is to reduce the impedance of the wiring. This is done by increasing the size of the conductors. Where the total voltage distortion is the sum of internal and external distortion, these techniques reduce the internal contribution.

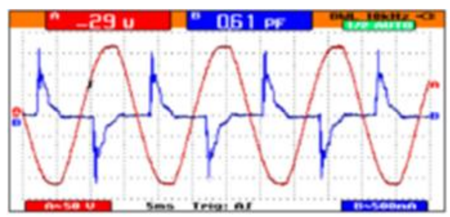
Harmonics voltages and currents in an electric power system are a result of non-linear electric loads. Harmonic frequencies in the power grid are a frequent cause of power quality problems. Harmonics in power systems result in increased heating in the equipment and conductors, misfiring in variable speed drives, and torque pulsations in motors. Reduction of harmonics is considered desirable.

Current harmonics:

In a normal alternating current power system, the current varies sinusoidally at a specific frequency, usually 50 or 60 hertz. When a linear electrical load is connected to the system, it draws a sinusoidal current at the same frequency as the voltage (though usually not in phase with the voltage).

Current harmonics are caused by non-linear loads. When a non-linear load, such as a rectifier, is connected to the system, it draws a current that is not necessarily sinusoidal. The current waveform can become quite complex, depending on the type of load and its interaction with other components of the system. Regardless of how complex the current waveform becomes, as described through Fourier series analysis, it is possible to decompose it into a series of simple sinusoids, which start at the power system fundamental frequency and occur at integer multiples of the fundamental frequency.

Further examples of non-linear loads include common office equipment such as computers and printers, Fluorescent lighting, battery chargers and also variable-speed drives.



A compact fluorescent lamp is one example of an electrical load with a non-linear characteristic, due to the rectifier circuit it uses. The current waveform, blue, is highly distorted. In this example the voltage waveform is also distorted from a sine wave, due to many such non-linear loads on this power system.

Voltage harmonics:

Voltage harmonics are mostly caused by current harmonics. A non-linear load will not directly cause voltage harmonics unless it is injecting power. However, the voltage provided by the voltage source will be distorted by current harmonics due to source impedance. If the source impedance of the voltage source is small, current harmonics will cause only a small voltage harmonics.

III. CONCLUSION

The proposed DPC-based compensation scheme reduces negative sequence currents injected by an uncompensated electric traction system using any power transformer connection. This technique can be used to reduce the current THD to values complying with international regulations, and additionally regulates the power factor observed in the common coupling point between the traction substation and the grid. Also, the compensation method based on the instantaneous power control algorithm with direct space vector representation, reduces the system's current THD to allowable ranges (<20%) and reduces the overall unbalance from 97% to 18% for worse-case operation. The compensation algorithm is able to control the power factor measured at the common coupling point under all considered conditions, with a very short transient thanks to the fast dynamic response of DPC.

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